

2022 White Paper

VIX Daily Directional Prediction



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Introduction

The importance of the CBOE Volatility Index (VIX) cannot be overstated given its role as one of the key indicators for practitioners and policymakers to gauge the forward-looking market condition. Coined as the ‘fear’ index, the predictability of this index has far-reaching consequences beyond the US financial market. However, naturally, the attention to this index makes it one of the most efficient markets to incorporate news in the global financial market.

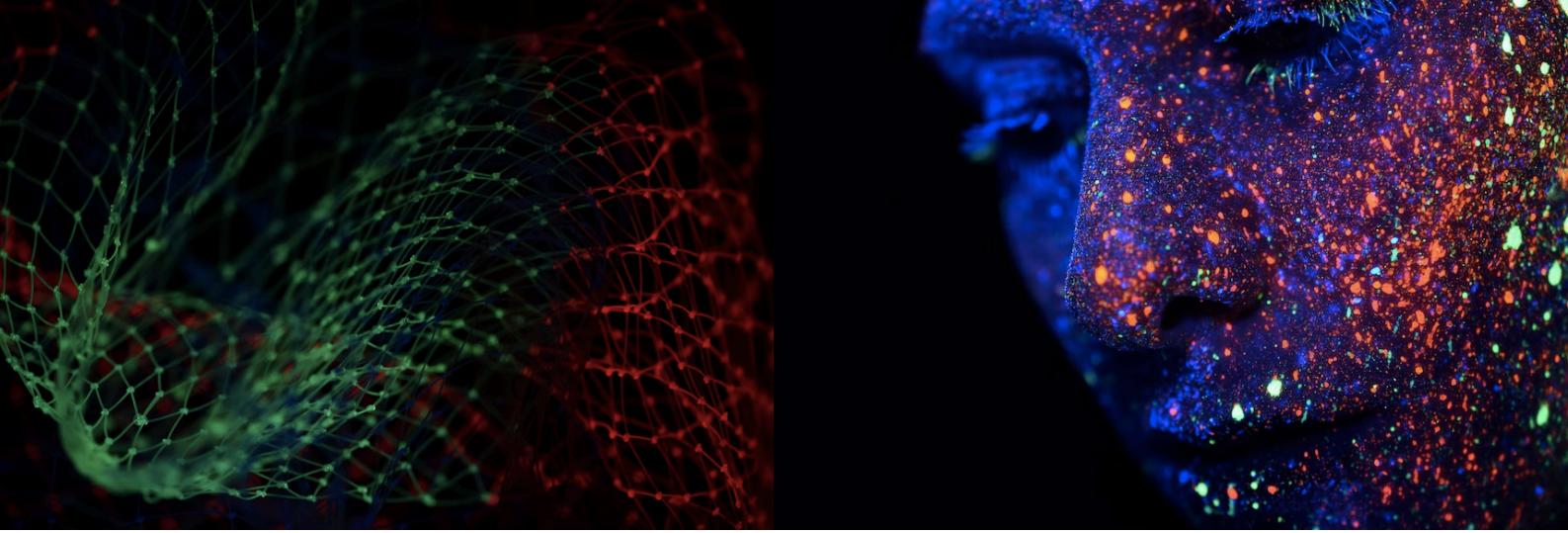
To drive the long-short investment decision, we designed and implemented an **Automated Adaptive Machine Learning Framework** to predict the next day’s directional movement of VIX. The Framework performs binary classification based on a **unique list of 278 features** comprised of historical time-series segregated in 14 categories, covering fundamental and technical indicators of the S&P 500 index information, global market indexes, industry subindexes, major commodities, foreign exchange markets, corporate and government bond, US macroeconomic indicators and seasonality.

We performed historical predictive testing and economic backtesting between January 2010 and December 2020, and online testing from January 2021 to date.

*The average accuracy score of historical predictive testing is **55.71%**
The economic backtesting over 11-year yields over **2200%** of profit in VIX return*

*The predictive accuracy score of online testing is **61.75%** (2021) and **59.51%** (2022 to date)*



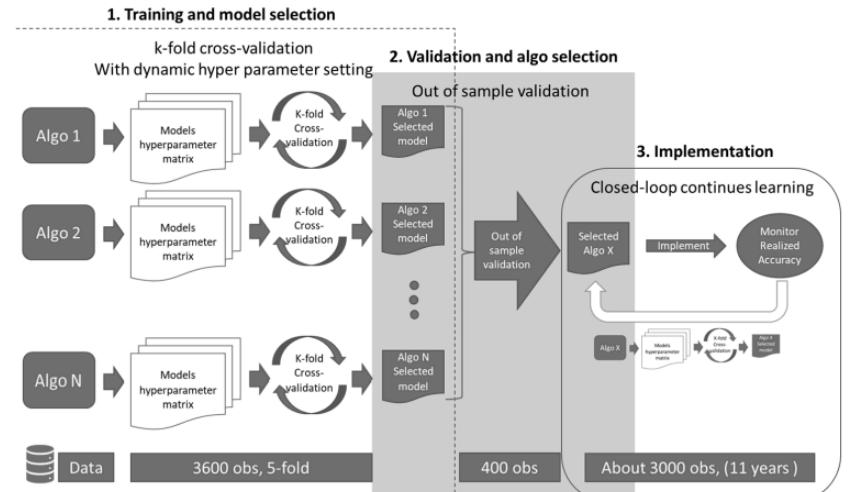


Methodology

We built the Automated Adaptive Machine Learning Framework to predict the next day's directional movement of VIX¹. The Framework is comprised of multiple classifiers with AutoML for Hyperparameter Optimization (HPO), Automatic Feature Selection from Highly Interpretable Model, and stacking model ensembles.

The learning process runs continuously in a closed loop. We use 16-year daily data (4000 data points) with 278 features for model training. The Framework selects the optimal ML model among multiple classification algorithms, and use the model for forecast the next day's VIX direction.

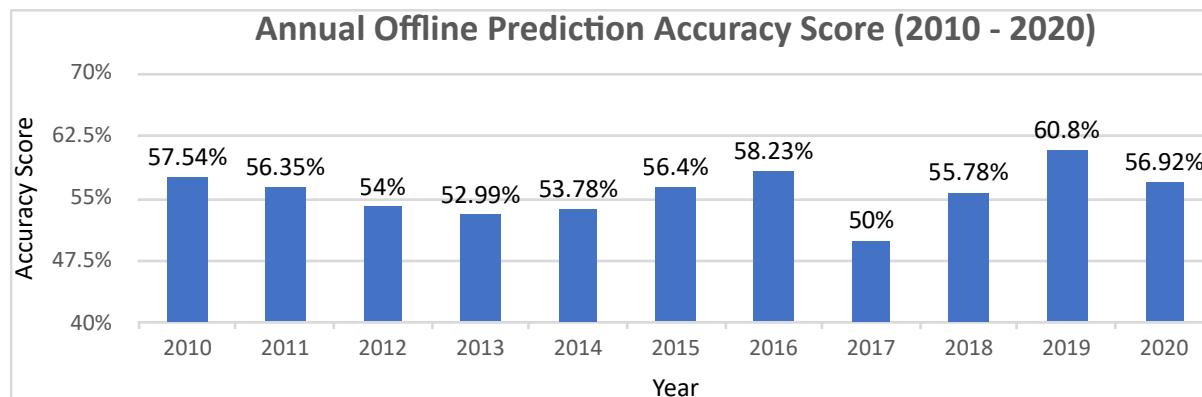
During model inference, the predictive performance is monitored by the Framework. When the data drift and/or model decay are detected, a new model training process is initiated, and a new model is deployed to replace the existing model, that prevents the overall performance deterioration.



¹ Bai, Yunfei and Cai, Charlie Xiaowu, Predicting VIX with Adaptive Machine Learning (January 26, 2022). Available at SSRN: <https://ssrn.com/abstract=3866415>

Machine Learning Model Performance

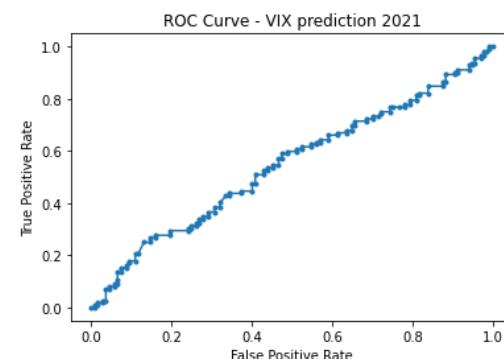
Applying the Automated Adaptive Machine Learning Framework on historical data between 2010 and 2020, the 11-year offline prediction yields average **55.71% of accuracy score**.



The classification report for the historical data prediction

	Precision	Recall	F1-score	Confusion Matrix	
Class = Down	0.59	0.51	0.54	727	709
Class = Up	0.53	0.61	0.57	511	808

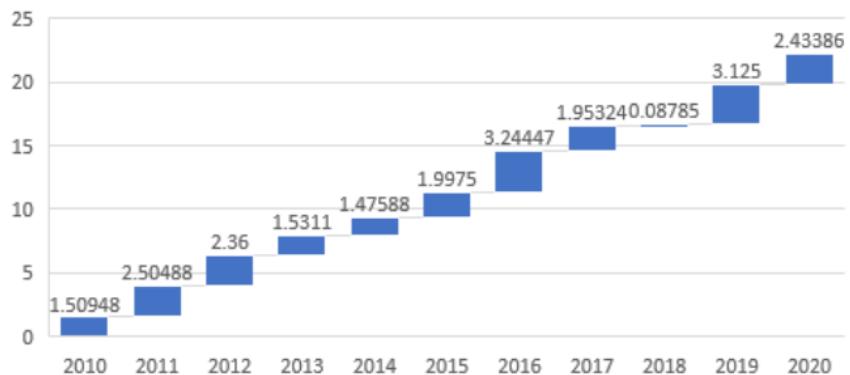
The daily online prediction has been implemented since January 2021. In 2021 the framework produced **61.75%** of prediction accuracy score, and **59.51%** in 2022 year to date of 24th August.



Economic Performance

We performed a backtesting by using offline and online prediction in a **VIX spot trading signal for a long-short strategy**. Although the VIX spot is not directly tradable, there are options and futures securities that one can construct a portfolio to trade by tracking the VIX directional movement. Here we consider a simulated strategy that invests a fixed amount of capital on VIX spot daily without compounding and risk control, as a size-weighted signal accuracy test. The size of profit and loss demonstrates how the directional prediction performs in different market conditions.

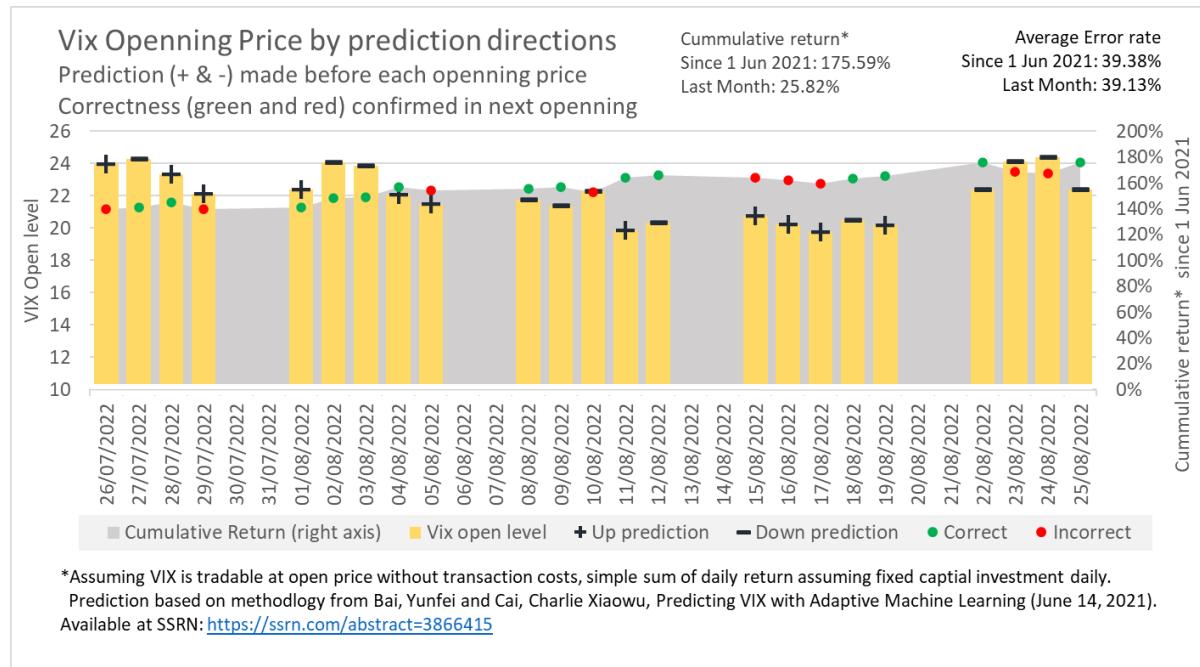
The backtesting results using offline prediction for 2010 - 2020 is shown below. The strategy returns **2200% profit** with simple summation over 11 years.



The low return in 2018 was due to missing one spike in February, which can be prevented by applying a risk control to the trading strategy.

The prediction accuracy score is not the only criteria that matters economically. In 2017 the accuracy score is lower, however the size of return is reasonable. The predictive model weighs both direction and magnitude of VIX variation, and often generates higher accuracy when the VIX movement is relatively large.

Since June 2021, the daily online prediction has been connected to a trading platform for strategy testing. The chart below illustrates the statistical and economic performance of daily VIX directional prediction with 2-day interval, over 30 days (2022/07/26 to 2022/08/25).



In the chart, the + and – indicate the prediction direction before the opening². The VIX opening level is indicated in the amber bars and left axis. The correctness of the signal will be confirmed in the next opening indicated by the green (hit) and red (miss) dots in the next period (the next bar on the right). These dots also indicate the level of cumulated return which is also further illustrated by the grey shaded area and measured by the right-hand side axis.

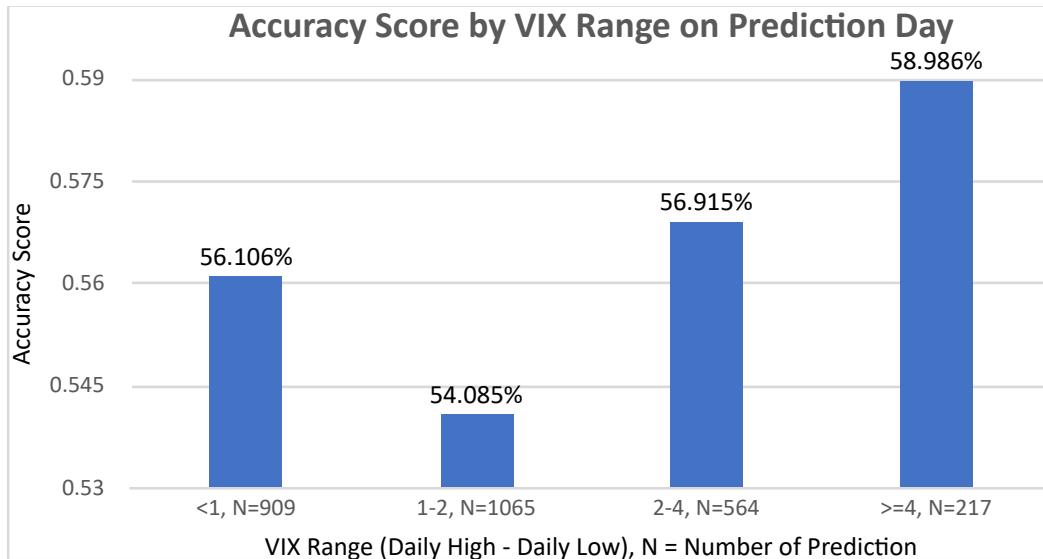
On the top right, the cumulated returns³ and the error rate are reported for the time period starting from 1st June 2021 for 23 days.

² A note about the alignment of the signal and date: Note that we have aligned the prediction to the next trading day indicating this signal is produced right before that opening level. This is different from the date and signal in the data table but they are consistent and both correct. The prediction was made using the data up to the close of the prediction date (in the data table). This prediction will be also available before the next market opening (in this picture).

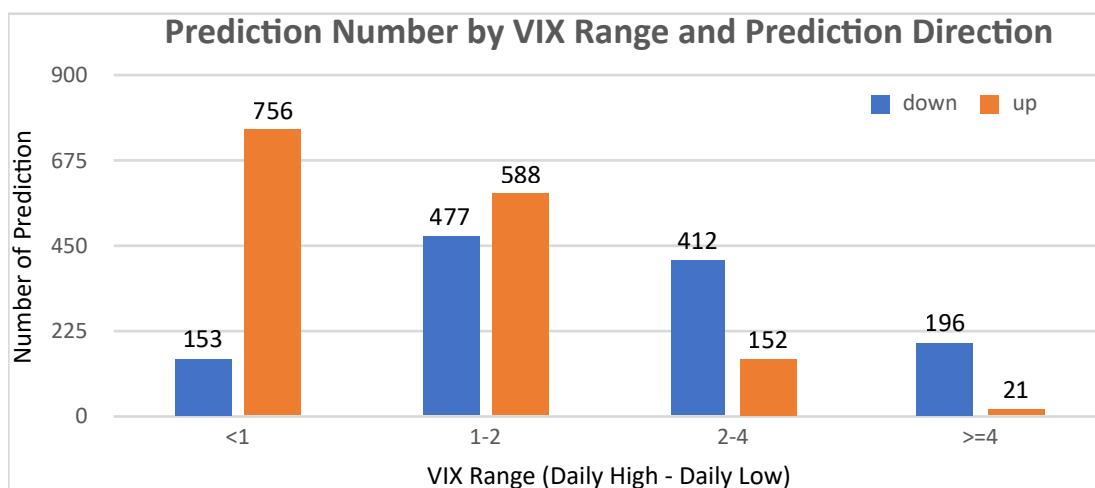
³ As in backtesting, although we operationalize this in real-time, these are not the real return as VIX are not directly tradable. The real investment profit of a similar long-short strategy will be further affected by tracking errors in the mimicking portfolios and instruments, transaction costs, leverage and financing costs.

Appendix

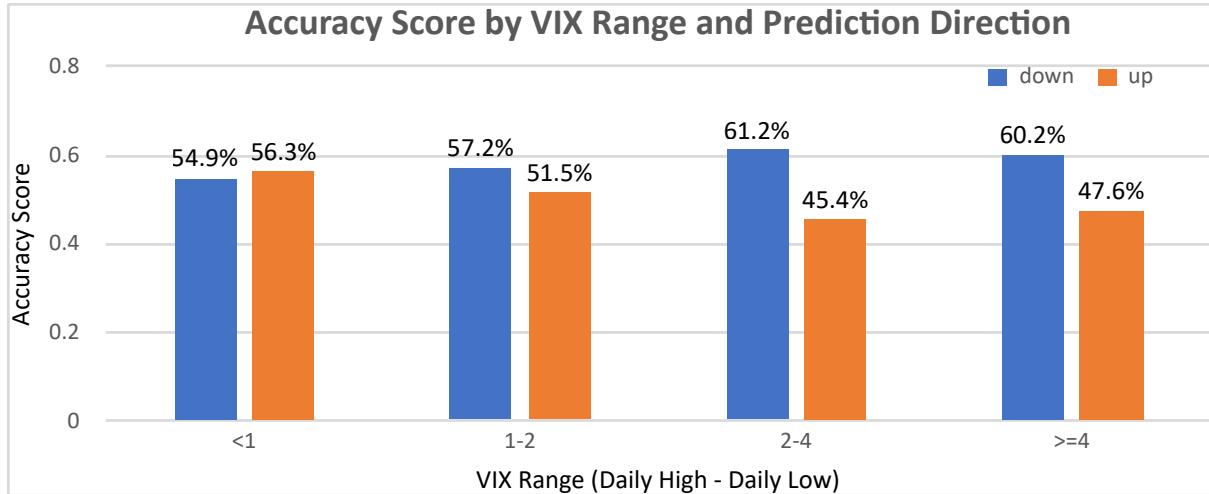
How does the VIX range affect the model accuracy score?



In general, the model performs the best when the intraday VIX range is either very high (larger than 4) or very low (lower than 1). Looking further into the division of up and down prediction reveals that when the intraday volatility is very low or high, the model will produce more one-sided predictions which are also more accurate as well.

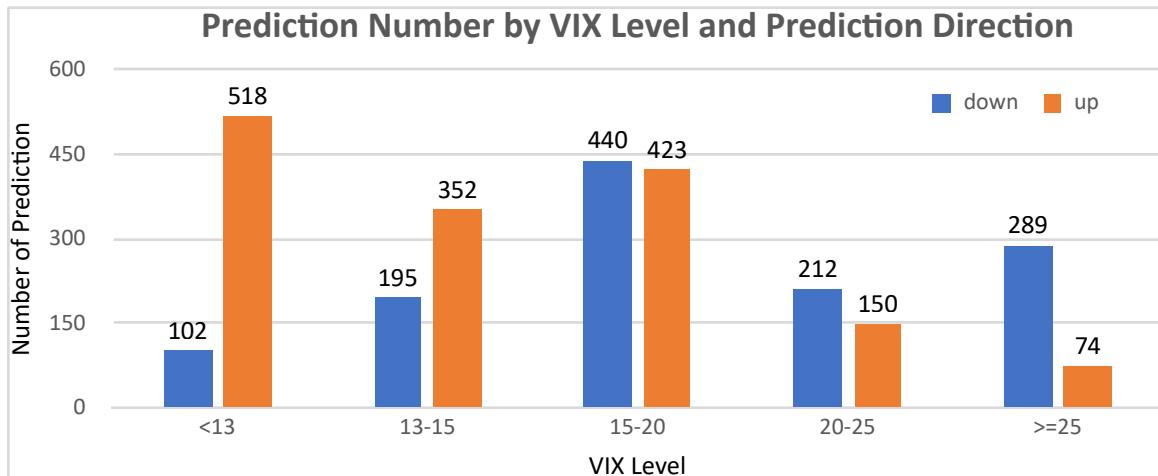


It shows that when the intraday disagreement of the VIX is high, the algorithm will be more likely to produce down than up predictions (in the 2-4 and >=4 groups) and vice versa (in the other two groups on the left).

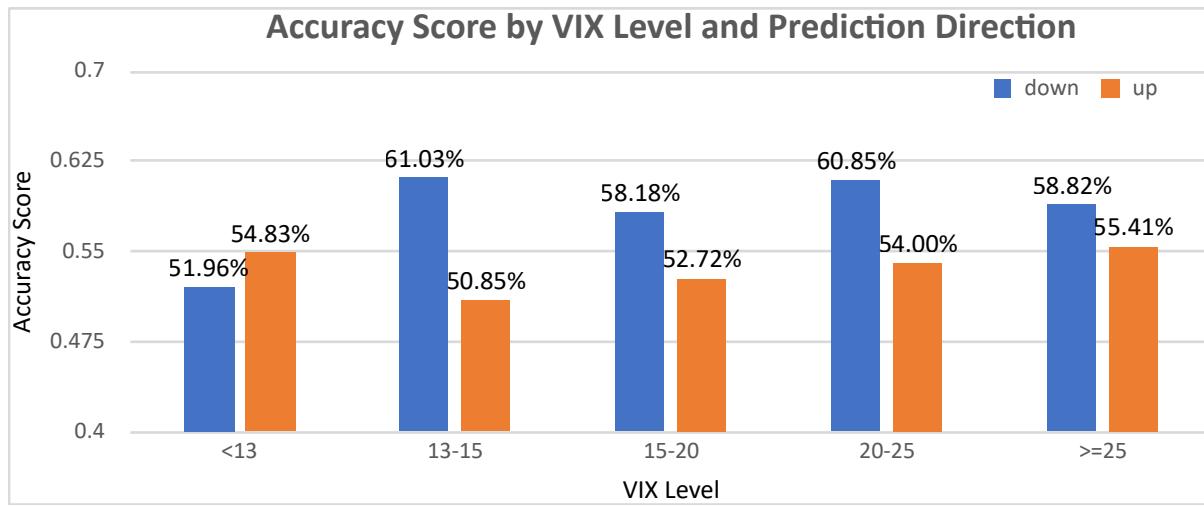


In general, the down prediction's accuracy increases with the intraday range while the up prediction has the opposite pattern. Overall, this confirms the machine is doing the right thing to produce the asymmetric prediction pattern produced conditional on the intraday volatility level.

How does the VIX level affect the model accuracy score?



In relative terms, the prediction follows a mean reverting pattern. When the VIX level is low (those groups on the left), up prediction is more likely and when the VIX level is high (those groups on the right), down prediction is more likely.



In general, down predictions turn out to be more accurate which partly reflects the unconditional distribution of the more small downs but fewer big ups or spikes of VIX. The exception is when VIX is very low (lower than 13) the algorithm predicts up much more often and these up predictions are much more likely to be correct.

For these analyses, we do not intend to suggest that one should use the prediction conditionally (note predictions in all categories are higher than 50% accuracy rate) but rather to show that the algorithm has its reason to produce certain ‘asymmetric’ prediction patterns in different market conditions. If there is a more systematic approach to improve the accuracy of the overall prediction, the algorithm should have picked up. Having said that, if one’s application is only relevant to a certain region of the VIX distribution or VIX intraday range, then this information would be useful for evaluating the effectiveness of the prediction for that application.

